(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 234 768
A2

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: 87300911.2

(51) Int. Cl.4: B01F 3/04

(22) Date of filing: 02.02.87

(30) Priority: 17.02.86 GB 8603904

(43) Date of publication of application:
02.09.87 Bulletin 87/36

(84) Designated Contracting States:
AT BE DE ES FR GB NL

(71) Applicant: IMPERIAL CHEMICAL INDUSTRIES PLC
Imperial Chemical House Millbank
London SW1P 3JF(GB)

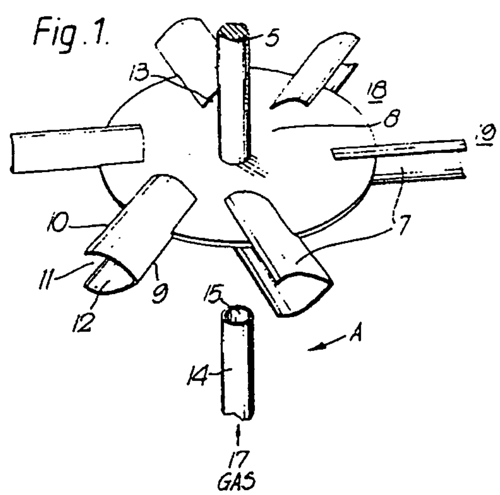
(72) Inventor: Middleton, John Colin
109 Mount Pleasant
Daveham Cheshire(GB)
Inventor: Ramshaw, Colin
4 The Spinney
Norley Cheshire(GB)

(74) Representative: Draggett, Peter Thornton et al
Imperial Chemical Industries PLC P.O. Box 6
Bessemer Road
Welwyn Garden City Herts AL7 LHD(GB)

(54) **Agitators.**

(57) A turbine agitator assembly comprising
a reservoir for liquid,
a rotor mounted in the reservoir and with a plurality of radially extending blades, and
means for sparging a fluid into liquid in the reservoir, the fluid sparging means and the rotor being so constructed and arranged that, in use, the rotor blades (submerged in the liquid) and/or the liquid flow they generate disperse the sparged fluid,
characterised in that each of the blades is hollow and has a discontinuous leading edge, only a single trailing edge along an acute angle, no external concave surface and an open radially outer end.

Fig.1.



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AGITATORS

This invention relates to agitators for the dispersion of a fluid in a liquid.

Disc turbine agitators with a plurality of axially aligned plane paddle blades are known for the dispersion of sparged gases as small bubbles in liquids in tanks and the concomitant mixing of the tank contents. In use, a vortex low pressure zone forms behind each rotating blade of the turbine, and with the gas flow rates frequently encountered in industry, the gas tends to collect and be held as a cavity in this zone; this disadvantageously reduces dispersion and mixing efficiency and can cause turbine blade erosion. The same problem would be found with a sparged liquid less dense than the tank liquid. We have now designed a turbine agitator in which vortex formation and its deleterious consequences are minimised, and which provides efficient dispersion and mixing.

Accordingly, the present invention provides a turbine agitator assembly comprising
a reservoir for liquid,
a rotor mounted in the reservoir and with a plurality of radially extending blades, and
means for sparging a fluid into liquid in the reservoir,
the fluid sparging means and the rotor being so constructed and arranged that, in use, the rotor blades (submerged in the liquid) and/or the liquid flow they generate disperse the sparged fluid,
characterised in that each of the blades is hollow and has a discontinuous leading edge, only a single trailing edge along an acute angle, no external concave surface and an open radially outer end.

In conventional disc turbine agitators, we have found that vortices are generated where fluid flow is not streamline along the blade surface, but becomes 'separated', for example at projecting edges (e.g. the axial edges of conventional axially-aligned paddle blades), where a trailing external surface is concave, or where there is no acute trailing edge, e.g. with circular, elliptical, square or oblong cross-section blades.

We believe that any blade fulfilling the foregoing criteria for a blade of this invention will be suitable. Within this, the blade may have a symmetrical cross-section, having a circular, parabolic or elliptical section leading face merging smoothly into a sphenoidal (i.e. wedge shaped) or sharply elongate parabolic or elliptical section trailing part. It will be seen that the term 'trailing edge along an acute angle' thus includes both angular and sharply radiused edges. Parabolic or elliptical section leading faces are favoured as improving the streamline around the blade, although the leading part may also be sphenoidal. A preferred blade shape is a symmetrical aerofoil-like cross-section.

The blade is hollow and the leading edge is discontinuous, for example in the form of holes, or in the preferred form of a slot symmetrically disposed in the leading face of a symmetrical cross-section blade. The radially outer end of the blade is at least partially open, so that such a blade provides a scooping action which disperses and mixes by pumping the scooped liquid radially outwards.

Typical dimensions of a blade in the present assembly are:
blade length = D/4, projected height = D/5, where D is the overall rotor diameter.

Typically the blade will be made of conventional metals or plastics used for turbine agitator paddles.

In its general form the blade has two elongate axes, one radial and one transverse, defining a 'blade plane'. This blade plane will generally coincide with or lie parallel to any plane of rotation described by the blade in use, that is the blade is usually not set at an 'attack angle' on or with respect to the rotor shaft. However, this latter possibility is not excluded, but the skilled man will readily appreciate that the angle should not be so great that the trailing (or any leading) edge behaves effectively as an axially projecting edge, and/or any trailing part of the blade surface behaves effectively as a concave surface, in tending to produce substantial vortices.

The blades of the turbine rotor may be arranged in the same rotational plane or in any number of parallel rotational planes. It is preferred that the blades are arranged regularly within any one plane so that rotational balance is maximised. Preferably they are also (as apt) so arranged along the shaft and with respect to each blade in any other plane in accordance with routine engineering practice that torsional balance is maximised, for example, they are arranged with equal numbers of blades in each plane, and with corresponding blades in different planes axially in register or with all the planes regularly rotationally skewed with respect to one another.

The blades may also be set at any angle to the rotor shaft in an axial direction, other than a right angle in order to provide an axial component of the discharge flow.

The rotor may have 2 or more blades. The mixing efficiency of the turbine will generally increase with the number of blades in any one plane until such point that the blades are so close with

respect to their transverse dimension that in use the action of any one blade interferes with the action of the following blade. Similarly the useful number of planes of blades is limited by any mutual interference between the planes due to proximity. The addition of further planes of blades increasingly remote from a single axial sparging source may also not increase the fluide dispersing efficiency of the turbine, but may still assist mixing of the liquid and/or liquid-fluid dispersion in the reservoir.

Subject to the foregoing suitable blade numbers include 2 to 24 coplanar blades, typically 4 to I2, and up to 5 planes of blades, typically I.

Typically, dimensions of the rotor are determined by the size of the reservoir, and usually the diameter will be one third to a half the corresponding reservoir transverse dimension.

The fluid sparging means may have a single aperture, or multiple apertures such as a row, grid, rose or ring. Although the sparging of liquids, in particular those less dense than the reservoir liquids, is not excluded, the sparged fluid will often be a gas.

The rotor and fluid sparging means may be placed in any orientation and mutual position which ensures that the fluid is delivered either to the volume swept by the rotor blades or to any directly adjacent zone on which any liquid flow generated by the rotor blades impinges (in both cases 'the dispersion zone').

The rotor may be mounted in any orientation, although it will often be convenient to mount it upright with the sparging means mounted on the reservoir above or below it, e.g. spaced axially from it, so that the fluid may be delivered to the dispersion zone through the liquid essentially under gravity, either from below for a gas or liquid less dense than the reservoir liquid or from above for a denser liquid. The sparging means may then suitably be a hole, rose or ring coaxial with the rotor.

As is common with turbine agitators the blades will not generally extend from the rotor shaft itself but will each be mounted on an arm or an equivalent structure on the shaft. It will be apparent that an axial hole, rose or ring sparging means small diameter than the overall rotor diameter which does not overlap the blades will not deliver fluid to the dispersion zone without a deflector. In such a case the blades may conveniently be mounted extending from the periphery of a rotor disc, the disc acting as a deflector. With the typical blade dimentions given hereinbefore, the disc will typically be 3D/4 in diameter, where D is the overall rotor diameter.

The fluid may of course be delivered to a zone radially outside the volume swept by the blades, since the liquid pumped into this zone by the blades makes it a dispersion zone; a sparging ring may be used.

Alternatively, the rotor may be mounted crosswise with the sparging means mounted on the reservoir and spaced radially from it above or below, again conveniently to allow delivery essentially under gravity. The sparging means may then suitably be an axially aligned row, a transverse straight or arcuate row or a planar or curved grid depending on the rotor structure.

In another aspect the sparging means may be mounted on the rotor, for example as an aperture or apertures in front of each blade or spaced axially from the or a blade plane.

Orientations of the rotor appropriate to or compatible with the disposition of the sparging means and blades will be self-evident to the skilled man.

Although useful in all applications where dispersion of two fluid phases is required, the present assembly is particularly useful for gas-liquid mass transfer processes, and for low-shear thorough mixing, e.g. of sensitive substrates such as living cell fermentation suspensions or polymer latices or dispersions subject to ready degradation or coagulation.

The present invention will now be described with reference to three specific embodiments of the rotor and sparging means, depicted in Figures I, 2, 3 and 4.

In the Figures, a rotor 4 is rotatably mounted vertically within a reservoir 2 (not shown) capable of holding a liquid 3 (also not shown) to submerge the rotor 4. The rotor 4 consists of a shaft 5 (driven by an electric motor 6 -not shown) on which a plurality (four or six) radially extending blades 7 are mounted regularly about the shaft 5 in a single plane by means of a disc or arms 8.

Each blade 7 is of symmetrical uniform aerofoil cross-section with a single sphenoidal acute-angle trailing edge 9 extending the length of the blade 7. Each blade 7 is hollow and its leading face I0 has a symmetically disposed slot II extending the length of the blade 7. The ends I2 of the blade 7 are open. The blades 7 are mounted such that their central planes of symmetry are coplanar.

A means for sparging gas I4 is, in Figures I to 3, mounted on the reservoir below the level of and coaxial with the rotor. In Figures I and 2 it is a single aperture or a sparging ring of apertures which do not overlap the blades 7. In Figure 3 it is a sparging ring lying below a zone I9 radially outside the volume I8 swept by the blades in use. In Figure 4 the sparging means I4 consists of four apertured tubes mounted on, projecting from, and

communicating with the hollow interior of the shaft 5, and regularly spread between and coplanar with the blades 6. Their apertures I5 are in the trailing face I6 of each tube I4.

In use, the reservoir 2 is filled with liquid 3 to submerge the blades 7 of the rotor 4, which is then rotated in the direction of arrow A. Gas I7 is then supplied via sparging apertures I5 (in Figure 4 through the hollow interior of the rotor shaft 5 and rods I3) to the volume I8 swept by the blades (in Figure I by deflection by the disc 8) or the zone I9. In all cases liquid 3 is scooped in by the blades 7 through the slot II and discharged through the open blade end I2 into the dispersion zone I9. In Figures I, 2 and 4 the gas I7 flows over the outer surface of the blades 7, and in all cases the gas is dispersed in the zone I9.

Claims

I. A turbine agitator assembly comprising a reservoir for liquid,
a rotor mounted in the reservoir and with a plurality of radially extending blades, and
means for sparging a fluid into liquid in the reservoir,
the fluid sparging means and the rotor being so constructed and arranged that, in use, the rotor blades (submerged in the liquid) and/or the liquid flow they generate disperse the sparged fluid,
characterised in that each of the blades is hollow and has a discontinuous edge, only a single trailing edge along an acute angle, no external concave surface and an open radially outer end.

2. An assembly according to claim I, wherein each blade has a symmetrical aerofoil-like cross-section with a parabolic or elliptical section leading face merging smoothly into a sphenoidal trailing part.

3. An assembly according to claim 2 having a slot symmetrically disposed in the leading face.

4. An assembly according to claim 2 wherein the blade plane coincides with or lies parallel to the plane of rotation of the blade in use.

5. An assembly according to claim I wherein the blades are arranged regularly in the same rotational plane or in each of a number of parallel rotational planes.

6. An assembly according to claim 5 the blades are arranged in a number of parallel rotational planes having the same number of blades in each plane and corresponding blades in different planes axially in register or with all the planes regularly rotationally skewed with respect to one another.

7. An assembly according to claim 5 having 4 to I2 blades in a single rotational plane.

8. An assembly according to claim I wherein the blades are mounted on a horizontal rotor disc and the assembly is so arranged that in use the disc serves to deflect the sparging fluid to the volume swept by the blades.

9. An assembly according to claim I wherein the sparging means is so arranged in use it delivers the sparging fluid to a zone radially outside the volume swept by the blades.

I0. An assembly according to claim I wherein the sparging means is mounted on the rotor.

Fig.1.

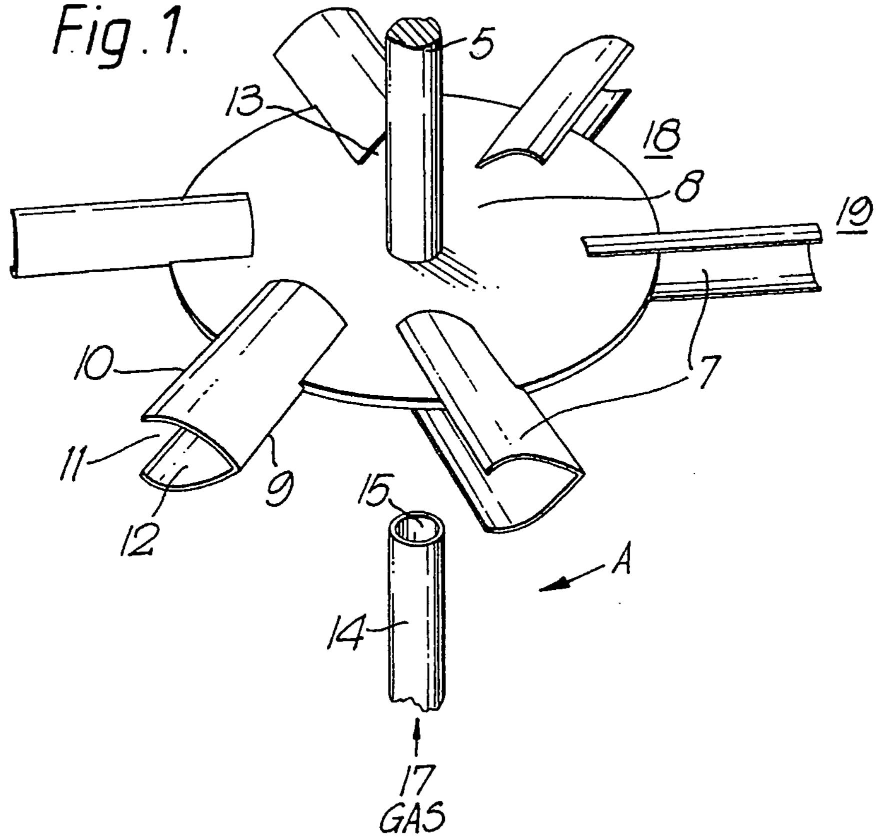
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Fig.2.

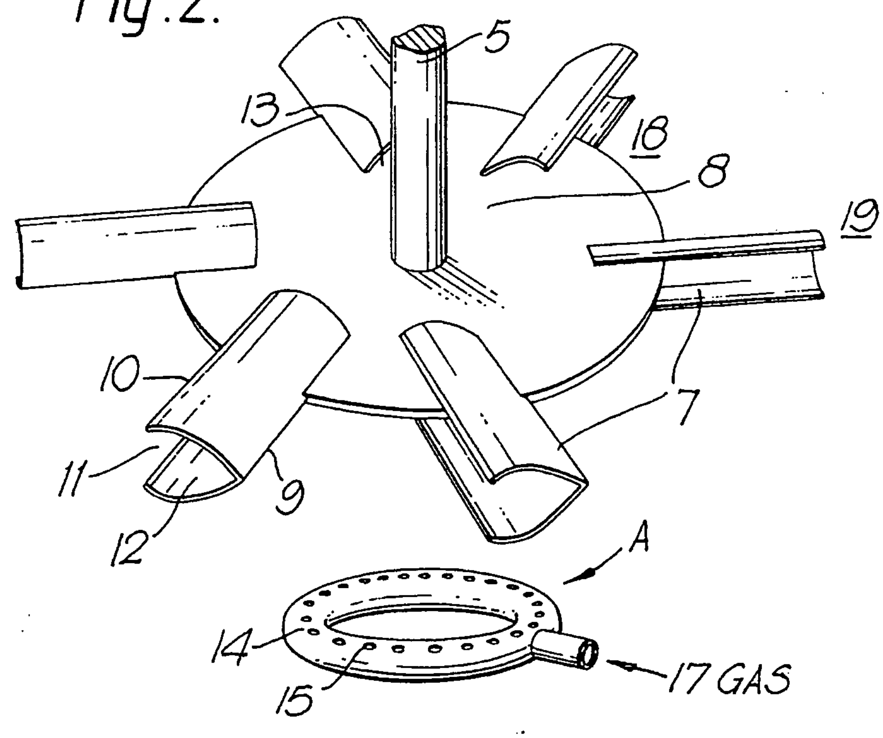
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Fig.3.

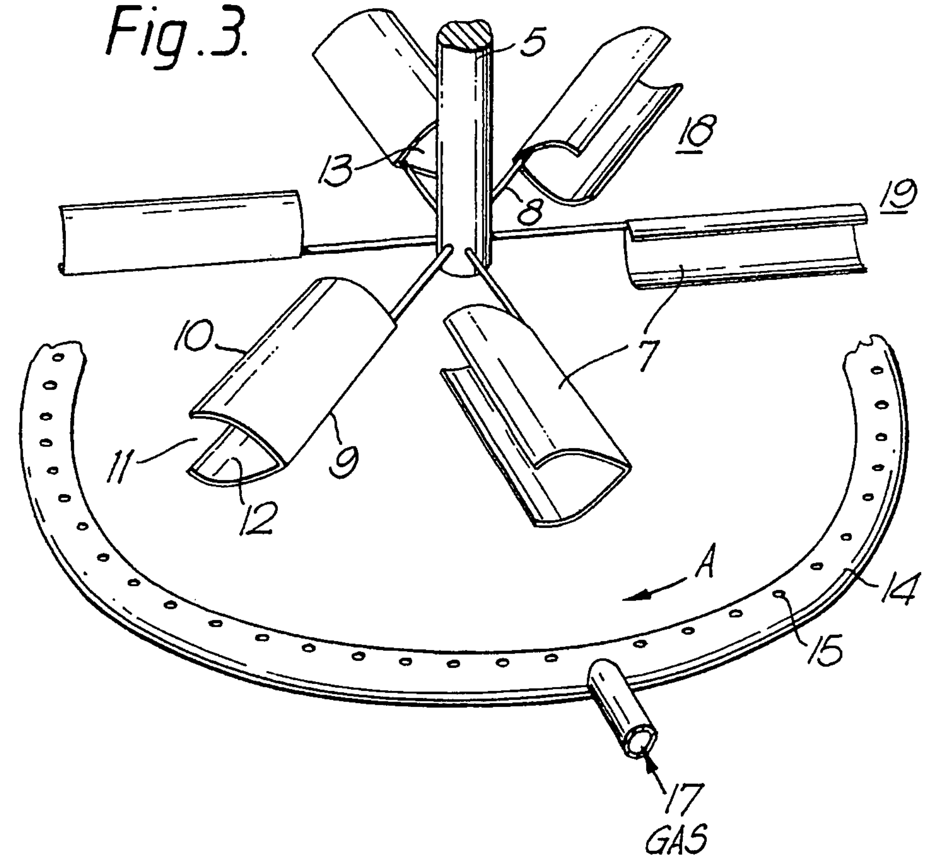
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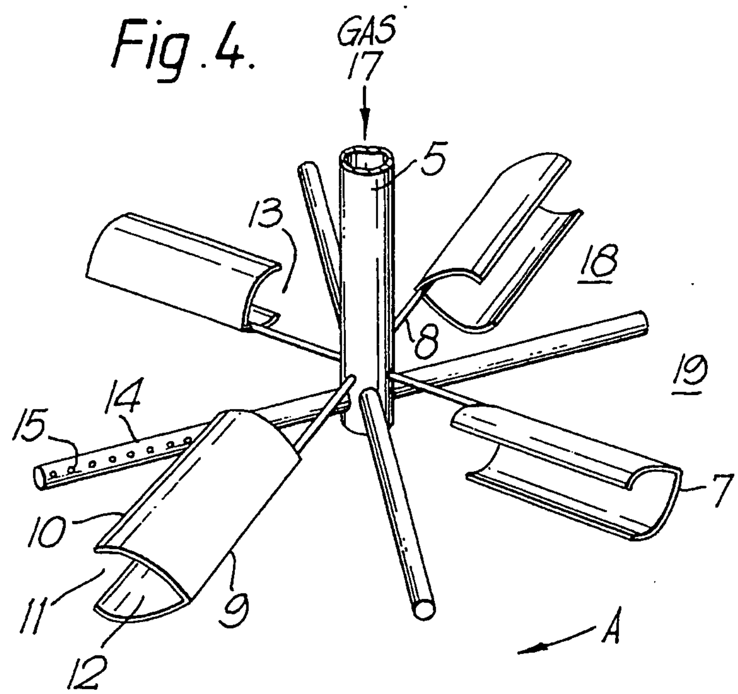
Fig.4.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